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Environmental geotechnics challenges in Australia

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Australia is one of the largest exporters of gold, iron ore and black coal in the world and a leader in mining and mineral-processing technology. The interaction of environment and infrastructure can readily be found in the main Australian industries. To keep its economic growth and national productivity, Australia should identify the environmental obstacles and show a sustained commitment to develop and maintain infrastructure for the twenty-first century. It is essential that researchers, industry professionals and government experts engaged in complex geoenvironmental issues conduct thorough investigations and find appropriate strategies for identifying and prioritising the major issues. A number of major geo-environmental problems in Australia are summarised below.

- *Tailing storage facilities:* Australia is a leading exporter of mined ores in the world with approximately A$138 billion in earnings in 2012 (Australian Mining, 2013). With these vast quantities of mined material come waste rock and tailings. These tailings and waste rock require storage, management and stringent environmental controls. The design, construction technology and management, foundation stability and drainage of tailings dams need further investigations for improving and identifying the best practice for safe construction.
- *Closed landfill sites:* Many closed landfills are located near or inside cities, even though they were originally established away from residential or commercial communities. Redevelopment of closed landfills is generally a challenging task owing to the complex behaviour of large settlement, creep and low shear strength of waste materials. Furthermore, the environmental risks posed by landfill sites (e.g., emission of landfill gas, release of leachate to the groundwater, sudden collapse of landfill embankment due to biodegradation and surface water infiltration) continue for a significant period of time after waste acceptance has come to a close.
- *Excessive erosion due to mining activities:* A major challenge to rehabilitate land, disturbed by the mining sector in Australia, is the reestablishment of a self-sustaining vegetative cover. A key challenge for achieving mine spoil reclamation is to prevent erosion on reconstructed landscapes long enough for successful revegetation to occur. Minimising erosion is thus an important step to reversing the loss of soil and building soil quality. Preventing erosion on reconstructed landscapes at mine sites can be expensive and complicated by the lack of organic cover and by the poor physical and chemical properties of stockpiled soil materials. Often, soils are highly dispersible because of high sodium content. Soil-stabilising polymers are commercially available, but there have been difficulties in successfully extending the technology from the laboratory- to field-scale application.
- *Erosion due to soil degradation and deforestation:* Studies in Australia's wet tropics, particularly in Western Australia, show that soils have limited capacity to recover from deforestation. The removal of soil by the action of water or wind, compounded by deforestation, poor agricultural practices, land clearing and overgrazing, is a major problem in the coastal regions of Australia. Damage to the land's productive capacity, because of poor agricultural practices such as the excessive use of pesticides or fertilisers, soil compaction or erosion of topsoil, eventually results in reduced ability to produce agricultural products. These issues need to be addressed in a proper way to ensure the continuation of sustainable productivity.
- *Landslides:* Geohazards represent a challenge to the safety of the Australian population through potential loss of lives and destruction of properties. Engineers and geologists should capture the effects of climate change in greater details in their research. The methods of analysis and interpretation should be improved and extended for landside hazards and risk assessment in Australia. Major challenges arise from uncertainties and the need to incorporate them in analysis, design and practice. According to Chowdhury *et al*. (2012), the main uncertainties are geological details, geotechnical, hydrological and historical data, external events information, project specifications and unknown factors including the effects of climate change.
- *Expansive soils and their effects on roads:* The shrink–swell property of soils presents a problem with the design and

construction of roads on expansive subgrades. Because of this characteristic, pavements are not achieving their design life owing to failures occurring early and, therefore, resulting in loss of pavement shape and premature rehabilitation. A large component of road infrastructure (around 185 000 km in length) is in New South Wales, and, currently, many roads are failing owing to the construction on expansive subgrades. This issue is presenting a hazard to public safety and is increasing the maintenance and rehabilitation costs in this state.

- *Land pollution and contaminated soil and groundwater:* Australia has encountered land and coastal pollution due to intensive agricultural, mining-industry and energy-sector activities. For instance, in most open-cut mining operations, final voids usually become artificial lakes in the rehabilitated landscape. In order to study and predict the possible characteristics of rehabilitated mine sites, it is necessary to have a sound understanding of the potential leachate transported from the mine spoil to the groundwater. Research is required to select and design the optimised remediation techniques for polluted groundwater or contaminated sites.
- *Soil acidity:* Soils containing iron sulphides produce sulphuric acid when exposed to air after being disturbed and often release toxic quantities of iron, aluminium and heavy metals. Acid sulphate soil (ASS) can be toxic to the marine and freshwater plants and animals. It contaminates water supplies and corrodes concrete and steel. It has been reported (CSIRO, 2006) that coastal ASS occupies an estimated area of 95 000 km^2, underlying coastal estuaries and floodplains near where the majority of the Australian population lives.
- *Soil salinity:* Soil salinity and dry-land salinity are two problems regarding the environment of Australia. Salinity is a concern in most states, especially in Western Australia. This state contains the majority of land affected by salinity in Australia, with around 70%. Over 2 million hectares in Western Australia are currently affected and a 75% reduction in sealed roads' life. Salinity in South Australia is also a problem in all principal agricultural areas, with 0·4 million hectares of land and wetlands impacted.
- *Transport infrastructure on deep soft soil deposits:* In Australia, the major cities lie along coastlines that consist of deep soft clay deposits, especially in Northern Queensland and New South Wales. These deposits can be categorised as problematic soils owing to their characteristic low-bearing capacity and high compressibility. The special design and construction approaches are required for rail, road, tunnel and bridge projects passing over or through highly compressible soft clay in the coastal regions.
- *Dredging:* Dredging is carried out to create new harbours, docks or waterways, or to deepen existing facilities in order to allow larger ship access. Dredging is necessary to create and maintain shipping and boating channels so that Australia can continue to engage in international trades, safe fishing and recreational activities. However, dredging spoils create disturbance in aquatic ecosystems, often with significant environmental adverse impacts.

In the past 50 years, Australia's urban areas, agricultural zones and coastal ecosystems have been extensively altered owing to deforestation and degradation of lands. Meanwhile, in the past decades, modern ground modification techniques and specialised equipment and methods have been developed. Improved construction materials with higher quality and lifespan have been introduced. Advanced composite materials offer higher strength, stiffness and durability compared to conventional materials. Now, more cost-effective materials and advanced computational and design tools are readily available. However, still, we are dealing with numerous uncertainties and significant challenges for the future development of innovative approaches and applications in geoenvironmental engineering projects. Highlighting the current geoenvironmental issues in Australia reveals that we need to investigate the applicability of modern ground modification techniques; critically analyse the design issues associated with various infrastructure projects; deeply understand the transport of contaminants; carefully choose and design appropriate techniques for complex geo-environmental systems; analyse the stability of various waste-disposal facilities and predict their potential environmental impact; and identify the unique properties and treatment of expansive, acid sulphate and saline soils, particularly those found in Australia.

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